APPLICATION NOTE

MODBUS TCP COMMUNICATION

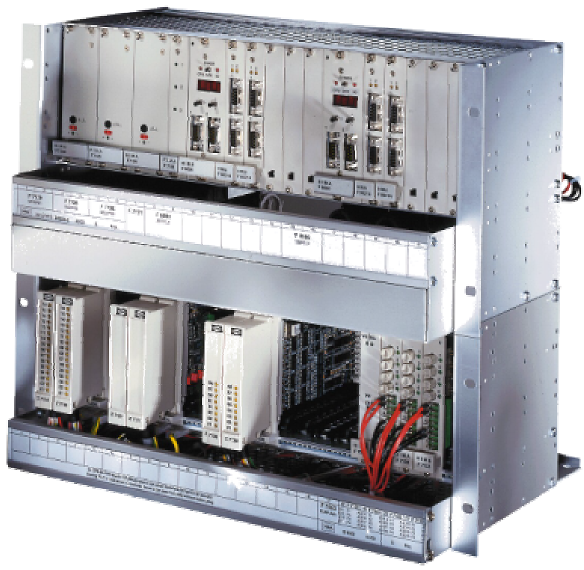
HIMA H41q/H51q

↔

Emerson Process Management DeltaV

Modbus-IDA
the architecture for distributed automation

Modbus TCP



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Industrial Automation

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HIMA Paul Hildebrandt GmbH + Co KG
PO-Box 1261
68777 Brühl

Phone: +49 (6202) 709 0
Fax: +49 (6202) 709 107

Email: info@hima.com

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1. Introduction

There is an increasing need for fast and voluminous data transmission between HIMA Safety PESs and different DCSs. Modbus TCP is a protocol which can fulfil this need. Modbus TCP communication combines the proven reliability of the Modbus protocol with the flexibility and speed of Ethernet networks. The well known Modbus Telegrams are coded into TCP packages and can than be communicated via Ethernet. As transport layer standard off-the-shelf Ethernet equipment like twisted pair network cables, switches and fiber optic converters can be used with communication speeds of up to 1 GB/s. In contrast to standard Modbus RTU the Modbus TCP protocol is multi master capable, meaning that several communication masters can access the same slaves for information.

The Modbus TCP communication protocol was made available to HIMA´s H41q/H51q and Emerson´s DeltaV system through market introduction of new communication modules in 2005 and 2006 respectively. Modbus TCP support was added to H41q/H51q systems through introduction of the new ethernet communication module F 8627X. A communication module from third-party supplier Mynah named Virtual I/O Module (VIM) added Modbus TCP capability to DeltaV. The Mynah VIM achieves this through simulating four DeltaV serial cards (eight serial cards for redundant layout) which are virtually mapped to the last I/O slots (61-64 for non-redundant and 57-64 for redundant communication) of the DeltaV systems eight possible I/O carriers. The way to configure the data communication and the applicable communication limitations is therefore the same like with standard DeltaV serial cards.

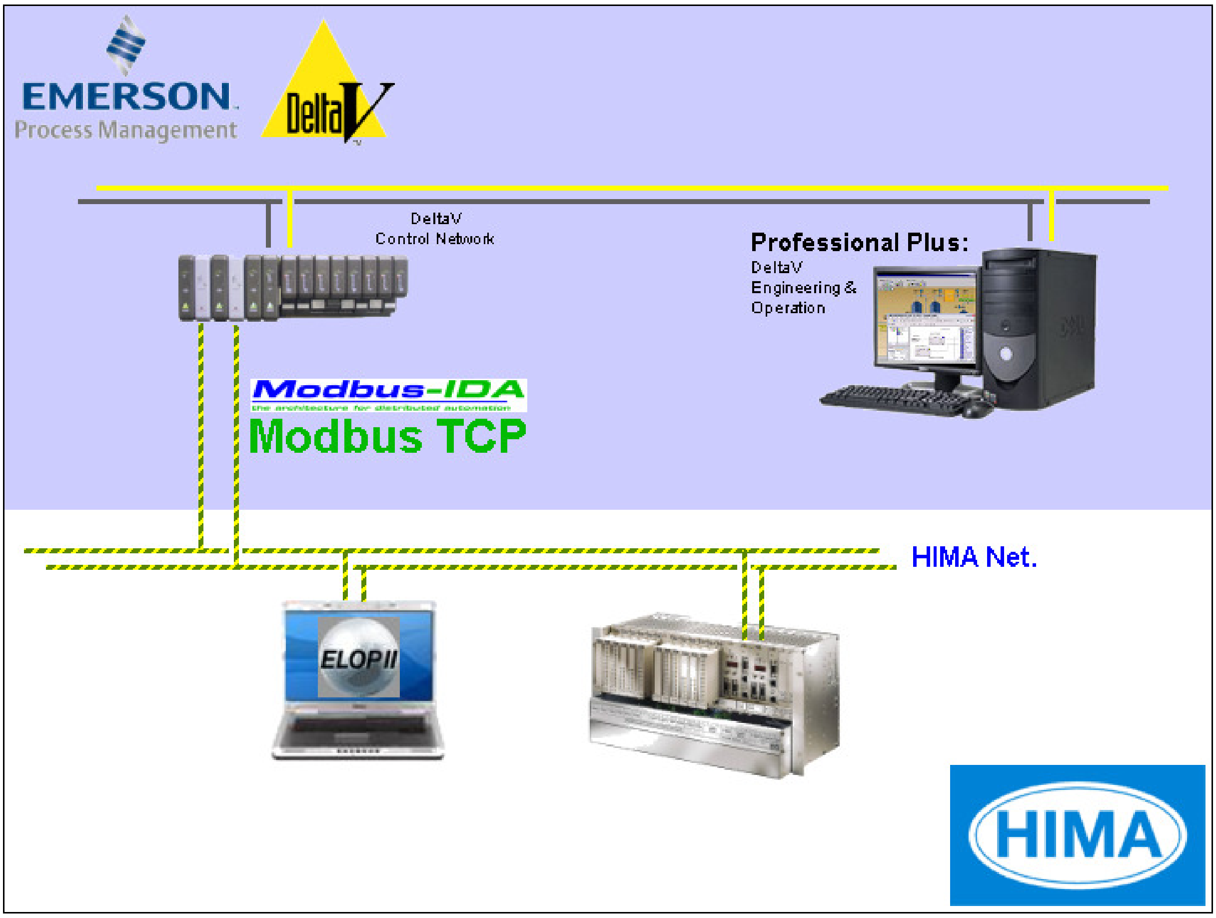

Figure 1.1 General Network Layout for Modbus TCP Communication

This Application Note should give an overview of the necessary configuration steps for establishing a Modbus TCP communication between HIMA's H41q/H51q safety PES and Emerson Process Management's DeltaV DCS.

As precondition for applying this Application Note general knowledge of the H41q/H51q PES and DeltaV DCS as well as configuring with ELOP II and DeltaV Explorer and Control Studio is assumed (see Recommended Literature [1], [2], [3], [4]).

2. Described Configuration

2.1. Detailed System Layout

The detailed hardware layout on which this Application Note is based is shown in Figure 2.1.

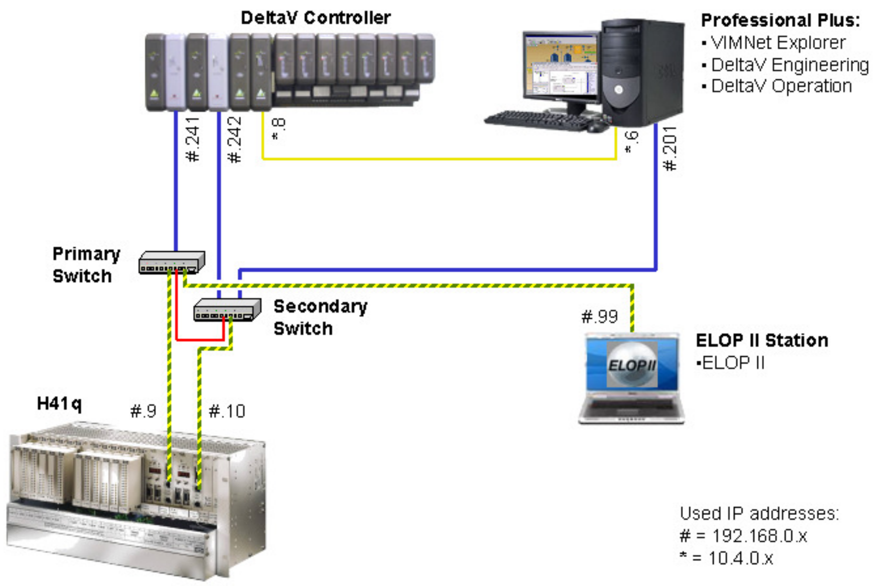

Figure 2.1: Network Overview for H41q/H51q ↔ DeltaV Modbus TCP Communication

The used hardware and software components are:

Hardware:	**Software:**
H41q/H51q PES	ELOP II Engineering Software
F 8627X Ethernet communication module	ELOP II license dongle
DeltaV MD Controller	DeltaV Automation Software
DeltaV Professional Plus Workstation	DeltaV System licenses
Ethernet Cat. 5 network cables	DeltaV serial port licenses
Industrial Ethernet Switches	

For detailed information about the explicitly tested hardware, software, firmware and Operating Systems refer to the Communication Test Report (see [6]).

2.2. Configuration of H41q/H51q Hard- and Software

The necessary configuration of an H41q/H51q PES for Modbus TCP communication consists of the configuration of the ethernet communication module F 8627X on the hardware side and of setting the IP address and defining communication variables in the application software.

2.2.1 Hardware Configuration

The hardware of HIMA safety systems can consist of one or several H41q/H51q safety PESs. The necessary hardware configuration for communication is the same for all PESs and simply consists of setting the **B**us **S**tation **N**umber (**BSN**) of all CPUs and configuring the F 8627X ethernet communication module. All settings are made via DIP switches when the module is removed from the rack.

Setting Bus Station Number (BSN):

The Bus Station Number is the address under which the safety PESs are addressed when serial communication via RS-485 is used. This address should be the same like the numbers ending the resource name in ELOP II from which the IP-Address is generated (see chapter 2.2.2 for details). There is one DIP-switch on each H41q/H51q CPU (e.g. F 8650X and F 8652X for SIL3 operation) setting the BSN and the serial transmission rate for the two integrated serial RS-485 interfaces. The BSN is set with switches 1-5 on DIP-switch S1 in a range from 1 to 99 using standard binary coding (for details about DIP switch settings on the CPU see [1] or the separately available CPU datasheets).

Configuring the F 8627X ethernet communication module:

The F 8627X has two DIP switches which are used for configuring the ethernet communication module.

S1	ON	OFF	Description
1	10 ms	0 ms	The "Timeout" is the timeframe within which the receiver must acknowledge receiving packets from the transmitter. It is set via the switches S1/1-5. Standard value: 10 ms (switch 1/1-5 "OFF"). Switches S1/1-5 can be combined by the user. 10 ms must be added for each combination of switches. HIPRO-S-DIRECT must be activated (switch 1/7 "ON").
2	20 ms	0 ms	
3	40 ms	0 ms	
4	400 ms	0 ms	
5	1000 ms	0 ms	
6	ID_IP ON	ID_IP OFF	For OS versions < 4.x no function (See also Chapter 5.2.3) ID_IP ON The bus station number (ID) which is set on the F 865x central module via switches (S1 1-7) is used as Res-ID if no Res-ID could be determined from the loaded user program. ID_IP OFF The bus station number (ID) which is set on the F 865x central module via switches (S1 1-7) is never used for the Res-ID.
7	DIRECT Mode enabled	DIRECT Mode disabled	HIPRO-S-DIRECT Mode must be activated if more than one bus configuration is required. HIPRO-S-DIRECT is supported beginning with the F 8627X OS version 3.x.
8	Passive Mode disabled	Passive Mode enabled	The Passive Mode controls the communication to the HIMA OPC server. Passive Mode enabled: The Token Passing between the F 8627X to the HIMA OPC servers is disabled. The HIMA OPC servers cyclically exchange data with the F 8627X, independent of the token owner. Passive Mode disabled: The Token Passing between the F 8627X and the HIMA OPC servers is enabled. The HIMA OPC servers only exchange data with the F 8627X if they have the Token.

S2	ON	OFF	Description
1	Ethernet Channel 1	Ethernet Channel 2	F 8627X allocation to the Ethernet channel 1 or Ethernet channel 2.
2	Mono	Redundant	Wiring of the modules (Not used in HIPRO-S-DIRECT Mode)
3[1)]	Auto-negotiation On	Auto-negotiation Off	Automatic adaptation of transmission rate (10/100 MBit/s) and duplex mode if is Switch S2/3 is ON.
4	100 MBit/s	10 MBit/s	The switch position of switch is only relevant if switch S2/3 (auto-negotiation) is OFF.
5[1) 2)]	Full duplex	Half duplex	The switch position of switch is only relevant if switch S2/3 (auto-negotiation) is OFF. Simultaneous sending and receiving if switch S2/5 is ON. Note on full-duplex operation: In network topologies where hubs are used, hubs must be replaced by full-duplex switches (hubs are not full-duplex capable).
6	2 OPC server	0	Beginning with the F 8627X OS version 3.x, the number of HIMA OPC servers (0 to 14) must be set via switches. Switches S2/6-8 can be combined by the user. If HIPRO-S-DIRECT is not active the number of HIMA OPC servers is four. For determining the Node Ids and IP addresses for the configuration of HIMA OPC server, see Chapter 6.8.1.4 and Chapter 6.9.1.5.
7	4 OPC server	0	
8	8 OPC server	0	

Figure 2.2: Recommended settings for F 8627X DIP switch S1 and S2

Figure 2.2 shows marked in red the DIP switch settings which are recommended for most ethernet communications.

- The switches S1/1-7 are used for internal H41q/H51q communication and should be sufficient for most applications when set as shown above.
- Switch S1/8 should be set to “Passive Mode enabled” to ensure also fast communication to the HIMA OPC DA Server by disabling time consuming Token Passing.
- Switch S2/1 should be set according to the position where the F 8627X will be placed. “Ethernet Channel 1” for placement next to CPU 1 or “Ethernet Channel 2” for placement next to CPU 2.
- Normally the communication modules are inserted redundant. Then Switch S2/2 should also reflect this.
- Switch S2/3 is set to “Off” as some networking devices do not support Auto-negotiation of transmission rate and duplex mode.
- Switch S2/4 and S2/5 should be set according to the networking hardware you use. Normally “100 Mbit/s” and “Full duplex” is suitable with nowadays networking hardware.
- Switches S2/6-7 should be set to determine the number of HIMA OPC Servers which are connected to this resource. (Be careful: In HIMA documentation the term “HIMA OPC Server” refers to the HIMA OPC DA Server as is the case here.)

2.2.2 Application Software Configuration

When programming a HIMA H41q/H51q safety PES within ELOP II there are two steps necessary to prepare the PES for data communication to any other programmable system via Modbus TCP or any other ethernet based communication method. These are: definition of an IP address and definition of variables to be transmitted through an ethernet communication module (definition of BUSCOM data).

Definition of the H41q/H51q´s IP Address:

The IP address of an H41q/H51q safety PES is defined through its resource name in ELOP II and consists of two subsequent addresses in network 192.168.0.x. The resource name must have eight alphanumeric characters and mustn't contain any spaces. For IP addressing the last two characters must be numbers. When you take XXXXXXnn as a resource name X represents an alphanumeric character and n represents a single digit number. The IP address of a communication module next to CPU 1 (channel 1) is calculated as (2•nn+1) while the IP address of a communication module next to CPU 2 (channel 2) is calculated as (2•nn+2). Valid resource names as example and corresponding IP addresses are listed in Table 2.1.

Resource Name	IP Address ch1	IP Address ch2
Burner01	192.168.0.3	192.168.0.4
V40a__02	192.168.0.5	192.168.0.6
H41qX_04	192.168.0.9	192.168.0.10
vessel05	192.168.0.11	192.168.0.12

Table 2.1: Example of IP address calculation

Declaration of BUSCOM data:

Each variable of type "VAR" or "VAR GLOBAL" which is listed in the variable list can be communicated via the standard communication protocols of H41q/H51q (Modbus via RS-485, Modbus TCP, Profibus DP and OPC DA). Binary variables can also be defined as "Events" and can be transmitted via OPC A&E. These BUSCOM declarations are the same for all communication protocols so exchanging protocols needs no additional effort besides exchange of the communication module if required.

The declaration of BUSCOM variables and events takes place in the Variable Declaration dialog which is available through double clicking the desired variable or selection of the appropriate tab when creating a new variable.

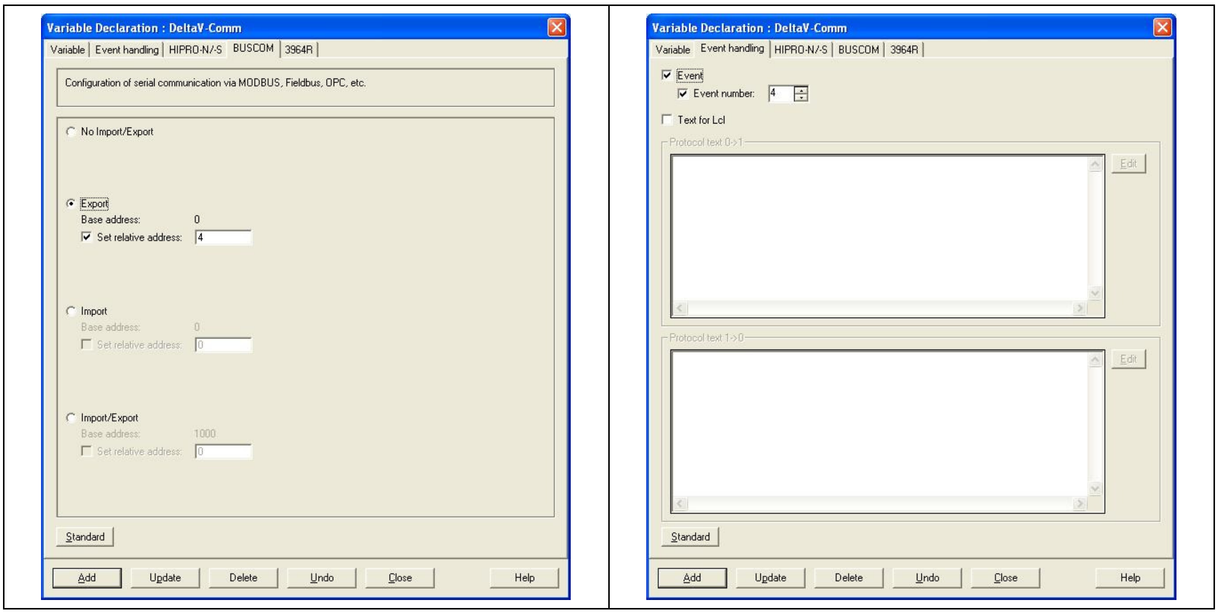

Figure 2.3: Declaration of BUSCOM variables and events

Boolean, Integer and Real variables can be declared as Export, Import or Import/Export beneath the "BUSCOM" tab of the Variable Declaration dialog. If necessary you can also declare specific addresses under which the data should be communicated. When not specified the variables addresses are automatically assigned by ELOP II during compilation. As preparation for Modbus TCP communication you should define fixed addresses to your communication variables to keep track of your used communication address space.

Note 1:
Variables defined as Import/Export use separate addresses for reading and for writing, according to Modbus conventions. Thus an Import/Export variable reserves twice as much memory space as an equivalent Export or Import variable. Import/Export addresses must be projected in both (read and write) memory areas.

Boolean variables can be made an event by checking the Event check box beneath the “Event handling” tab. Like with BUSCOM variables you can also declare specific addresses under which the event should be communicated.

Note 2:
If you define a spare range of communication addresses it is not necessary to download the H41q/H51q when adding new communication variables or events instead you can proceed with a reload of the PES. You can achieve this by inserting a dummy communication variable or event some addresses ahead of the actually used range.

2.3. Configuration of DeltaV Hard- and Software

The necessary configuration of the DeltaV DCS for Modbus TCP communication consists of the configuration of the ethernet communication module Mynah VIM, the simulated DeltaV serial cards and of the take-over of the communicated data in the application software of the DeltaV control modules.

2.3.1 VIM Configuration

The Mynah VIMs are installed next to the DeltaV 2-wide controller carrier on the left side. They are mounted, together with a standard DeltaV power supply, on a separate 2-wide controller carrier.

Note 3:
If necessary due to mounting space restrictions the 2-wide DeltaV controller and VIM carriers can be separated from the 8-wide DeltaV IO carriers by using extender sets which separate the carriers by means of special signal cables and extender modules.

Two standard ethernet Layer 2 switches are used as network nodes for Modbus TCP communication in the primary and secondary network. These switches are also certified for use with HIMA´s safe communication via safe**ethernet** to other H41q/H51q PES and they can also be used if additional OPC DA or OPC A&E Servers need to be used.

Note 4:
The Mynah VIMs require the use of two switches as coupling devices for redundant connections because the VIMs need a cross link cable between these switches (marked in red in Figure 2.1) to carry out their redundancy replication. Also for a redundant direct point-to-point connection (one DeltaV controller communicating to one HIMA PES) crossed network cables cannot be used. Instead two switches and a cross link cable between them are required.

The configuration of the VIM is carried out with Mynah's "VIMNet Explorer" which is not necessary for operation of the VIMs and can therefore be installed on a separate computer which needn't be permanently connected to the communication network. When the VIM needs to be configured initially or for expansion of available Modbus TCP devices the VIMNet Explorer must be connected via a Network Interface Card (NIC) which must reside in the same network range like the VIM itself. I.e. VIM host address 192.168.0.241 is only accessible from 192.168.0.x when the NICs netmask is 255.255.255.0. Keep this fact in mind when you encounter connection problems between VIMNet Explorer and the VIM.

When the VIMNet Explorer is initially started the tree consists just of the area "VIMNET" and the underlying "I/O Net" similar to the DeltaV Explorer's view. The initial configuration of the VIM to be ready for Modbus TCP communication requires the following seven steps:

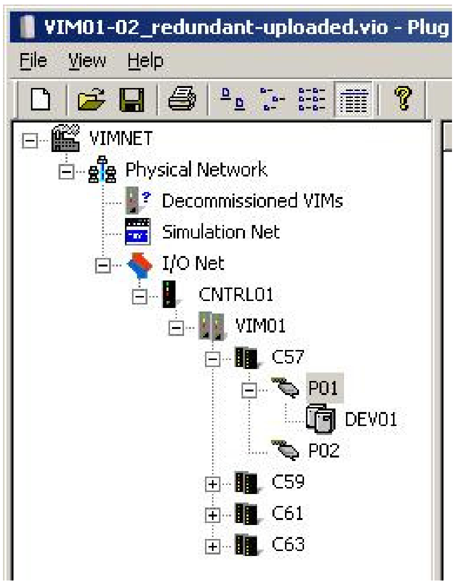

Figure 2.4: VIMNet Explorer Tree

1. Add a controller to which the VIM should be assigned using the context menu of I/O Net. Use the same name like in DeltaV Explorer to simplify identification of corresponding structures.
2. Add a VIM below the newly created controller using the controller's context menu.
3. Configure the VIM's properties according to Figure 2.5 to be of type "I/O VIM – Modbus TCP", select redundancy if necessary. Enter the appropriate IP addresses and subnet masks.

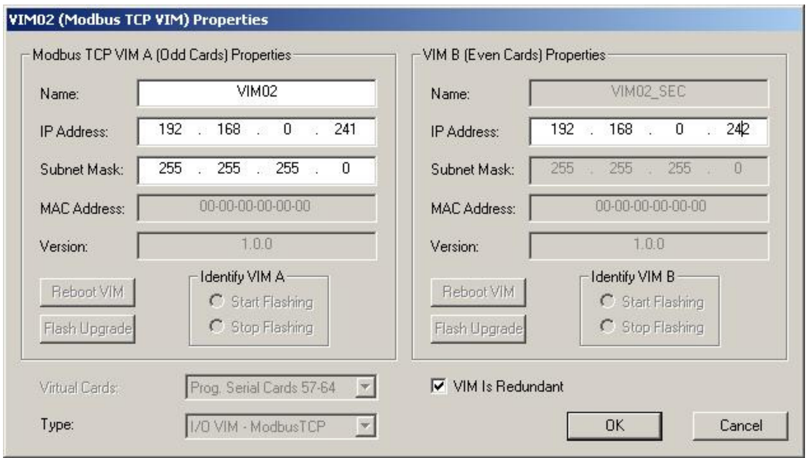

Figure 2.5: VIM Properties

4. Add a new Modbus device below the desired serial card. The device must be defined in VIMNet Explorer and DeltaV Explorer whereas the communication data (datasets) are only defined in the DeltaV Explorer.
5. Configure the device properties according to Figure 2.6 with Device Address and primary and secondary IP address of the H41q/H51q. The used Port should be set to 502 and the Number of Simultaneous Messages must be set to 1. For a simplex connection you need to set to "Simplex Device" and use just one IP address. A redundant connection can be set to "Redundancy with Switching IP" (which means the active VIM stays active when a connection failure to it's active slave occurs and it just uses the secondary IP address via the cross link cable) or to "Redundancy with No Switching IP" (which in turn means the master also switches when a connection failure to it's active slave occurs; this is the normal behaviour of the DeltaV redundant serial card).

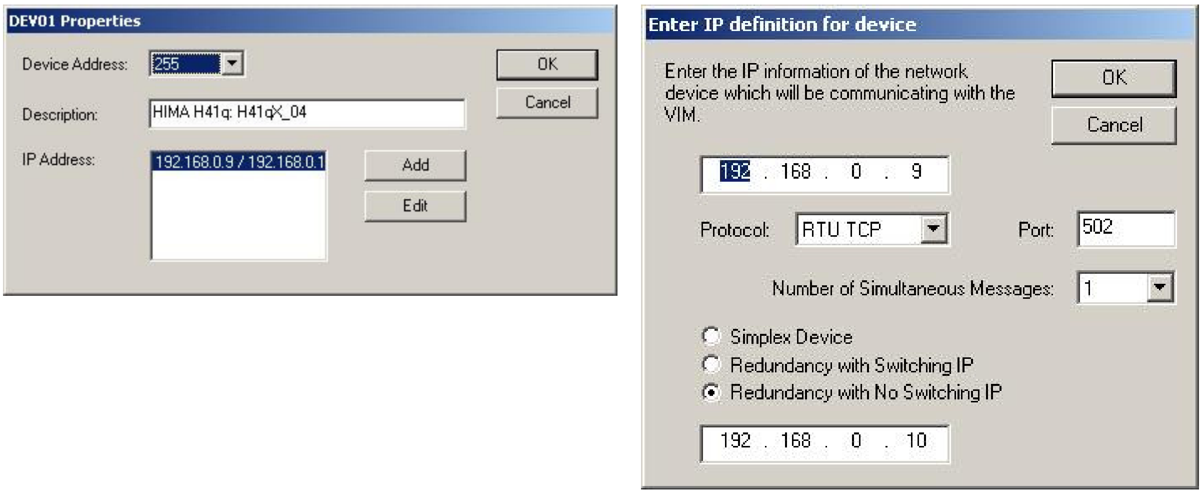

Figure 2.6: VIM Device Properties

Note 5:
HIMA's ethernet communication module F 8627X replies until firmware revision 4.14 with device address 255, regardless of its actual device address being set via DIP switches to the CPU. The DeltaV Modbus master should therefore be configured for this address because it would otherwise not accept protocols with this reply address.

6. Have a look at the area "Decommissioned VIMs" in VIMNet Explorer. You should be able to see the appropriate number of decommissioned VIMs if your network is correctly connected to the VIMs. Now you can commission the VIMs using the commission dialog via the configured VIM's context menus or via drag-and-drop of the decommissioned VIMs onto the configured VIM. Use the identify function of the commissioning dialog to keep track of assigning the correct VIM for primary and secondary module.
7. As a last step upload the configuration to the VIMs using the context menu and the "VIM Configuration Upload" command. Be sure to save your VIMs configuration to be able to use the VIMs diagnosis or to change the configuration starting from the saved point.

Note 6:
When you have problems finding the decommissioned VIMs disconnect them from their power supply, the network and their carrier. Keep them disconnected for approximately 30 seconds and then reinstall them (the same procedure like with not unassigned DeltaV controllers).

For further troubleshooting information refer to [5].

2.3.2 DeltaV Serial Card Configuration

The configuration of the simulated DeltaV serial cards is nearly the same like with standard serial cards. Only the device data type and the special data information differs for some data types. You also need to have one serial port license for each simulated serial port you use.

The serial card configuration starts with the port configuration. Select the port used in VIMNet Explorer for your first device and open the port properties. Set the configuration properties like shown in Figure 2.7.

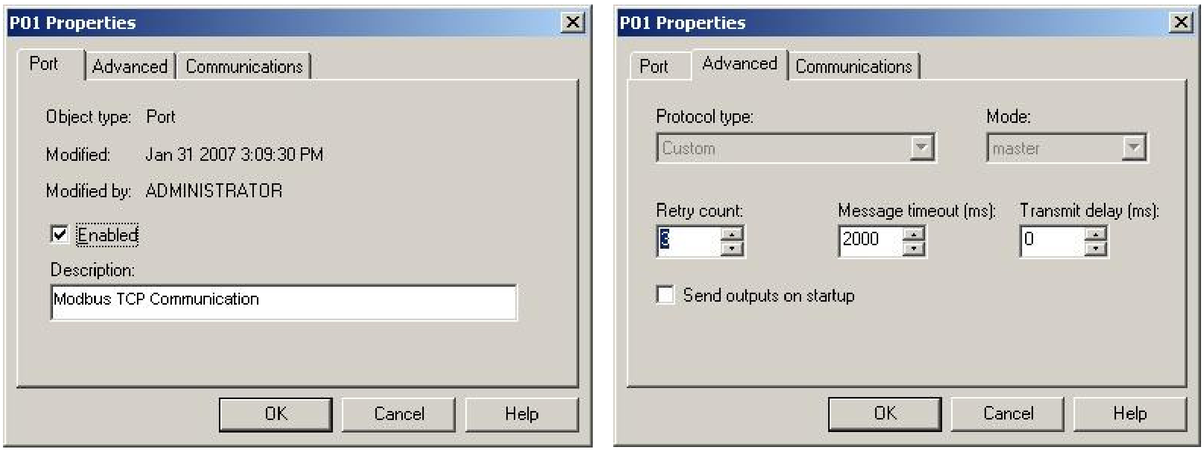

Figure 2.7: DeltaV Serial Port Properties

The "Retry Count" is recommended to be set to 3 so that delays in request processing on the slave side do not provoke communication disruptions. The "Message Timeout" could be set to slower values like the used 2000 ms but should be set to times well above the PESs cycle time. The configuration of the third tab "Communication" is not necessary for Modbus TCP communication as this tab applies only to serial communication.

The data for serial communication in DeltaV is organized in so called Datasets. One Dataset can contain up to 100 values (50 values for real data). One serial card port can handle up to 16 datasets in up to 16 devices (meaning 16 devices with each one dataset up to one device with 16 datasets). Each serial card offers two ports. One pair of VIMs supports in sum four redundant or eight simplex simulated serial cards therefore amounting to 12,800 respectively 25,600 data values which could be theoretically be imported to or exported out of DeltaV.

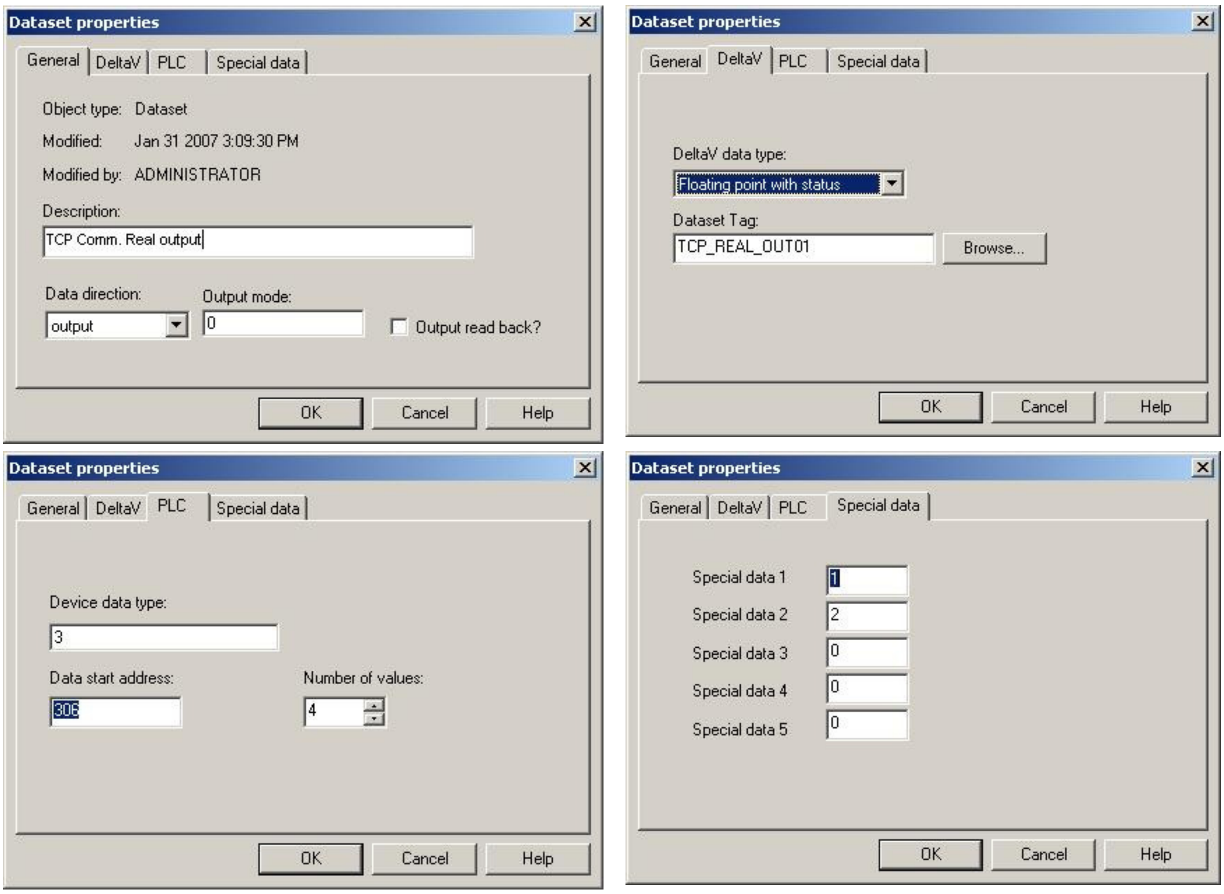

Figure 2.8: Dataset Properties

As an example the dataset configuration for output of real values is shown in Figure 2.8. Using the output read back option on the general tab requires definition the corresponding variables in the H41q/H51q PES as “Import/Export”. The dataset is assigned a dataset tag with which it can be browsed out of the application logic of the DeltaV control modules.

The demonstration application on which this Application Note is based utilizes reading and writing communication data as Boolean, unsigned integer and real values. The necessary settings for these data types in the datasets are shown in

Data Type	DeltaV Data Type	Device Data Type	Special Data	
			Data 1	Data 2
Boolean	Boolean with status	0	0	0
Unsigned Integer	16 bit uint w/Status	3	0	0
Real	Floating point with status	3	1	2

Table 2.2: Dataset Configuration settings

2.3.3 Application Software Configuration

Modbus TCP communication data can be referenced for input or output in DeltaV control modules via external reference parameters. When browsed the reference path looks like: “TCP_REAL_OUT01/R307”. The first part of the reference before the slash is the tag name while the latter part describes the register address.

Note 7:
There is an offset of one register address between H41q/H51q and DeltaV. The register number in a reference path like “TCP_REAL_OUT01/R307” connects to the register address 306 in H41q/H51q. However the “Data start address” on the PLC tab of the dataset properties refers to the correct address (see Figure 2.8) but the first created register within this dataset gets address 307.

This communication data can as well be referenced directly in analogue (AI) or discrete (DI) input blocks.

Communication data also consumes I/O licenses in the DeltaV system. Therefore binary input and output data should be bundled and unbundled to unsigned integer variables in DeltaV using “Binary Fan In” and “Binary Fan Out” function blocks like shown in Figure 2.9.

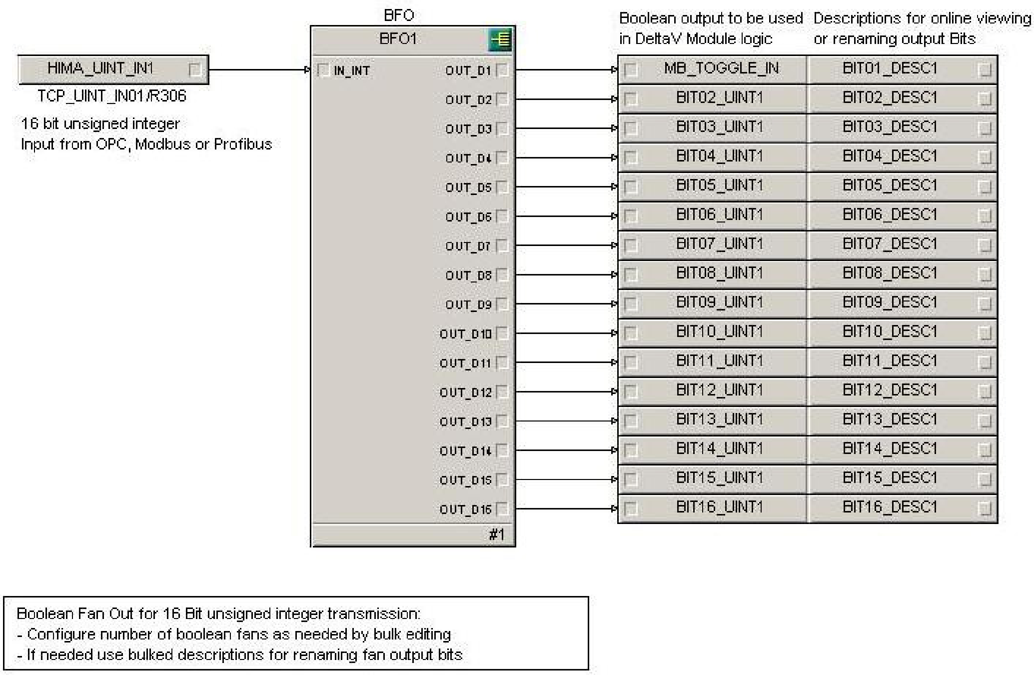

Figure 2.9: Unbundling Binary Input Data

These blocks can be imported as needed via the bulk import feature of DeltaV and than be copied together in one control module for import and one control module for export of binary data.

2.4. Validation of Modbus TCP Communication

The Modbus TCP communication between the H41q/H51q PES and the DeltaV DCS is supervised through the VIM Modbus TCP Master. The status changes are alarmed in the operator interface as controller status change after approximately ten seconds of inactivity.

For safety critical data transfer from DCS to PES like maintenance override switches a watchdog signal should be used for supervision of the communication. When the watchdog does not change all set maintenance override switches should be released. The watchdog should be implemented as a ramped unsigned integer variable to avoid malfunction through under sampling which could occur with binary signals.

The DeltaV Diagnostic Application and also the Mynah Diagnostic Application offer diagnostic support for troubleshooting like signal status, online signal values and communication counter. For more information about diagnostic support refer to [4] and [5].

Note 8:
When a Modbus TCP communication failure occurs the status of the simulated serial cards in DeltaV Diagnosis change to “Bad” displayed with a yellow question mark. After restoring communication it could be necessary to clear the fault using the “Clear Saved Fault Information” option in the context menu of a simulated serial card in DeltaV Diagnosis.

3. Summary

Modbus TCP communication between HIMA PES and the DeltaV DCS is an alternative to serial Modbus RTU communication via RS-485 or Profibus DP communication. The advantages of the described communication becomes effective for:

- Network layouts with several communication masters in one single network (due to multi master capability)
- Network layouts with larger numbers of HIMA PES as communication slaves (due to the large possible data volume of the VIMs)
- Larger data volumes to be transferred from one or several HIMA PES to a single DeltaV controller (due to faster speed [2 – 3 times faster than Modbus RTU] and lower susceptibility of communication cycle times to increasing data volumes)
- Network layouts where simplicity in connecting devices is preferred (due to the ability of integrating all HIMA PES communication in one redundant ethernet)

For other applications where the above mentioned advantages do not apply Profibus DP (fast and inexpensive but non-redundant and volume-limited) or Modbus RTU (inexpensive but slower and more volume-limited) are still viable alternatives.

4. Recommended Literature

[1] HIMA Programmable Systems
“The H41q and H51q System Families, Catalogue”
HIMA GmbH + Co. KG Bruehl, Germany, 2007

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Fisher-Rosemount Systems, Houston, USA, 2006

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“Modbus TCP Master Driver for DeltaV Virtual I/O Module”
Mynah Technologies, 2006

[6] HIMA Communication Test Report:
HIQuad-DeltaV Modbus TCP V. 1.0
HIMA GmbH + Co. KG, Bruehl, Germany, 2007

5. Document Revision and Release History

Revison:	Contents / Changes:	Release Date:
1.00	Initial Release with redundant Modbus TCP connection between HIMA F 8627X (SW: V4.14) and Mynah VIM (SW: V3.6.3).	2007-02-13
1.01	Minor improvements of graphically faulty embedded pictures.	2007-07-27

HIMA
... The safe decision

HIMA Paul Hildebrandt GmbH + Co KG
Industrial Automation
PO-Box 1261   68777 Brühl, Germany
Phone: +49 (6202) 709-0   Fax: +49 (6202) 709-107
Email: info@hima.com   Internet: www.hima.com